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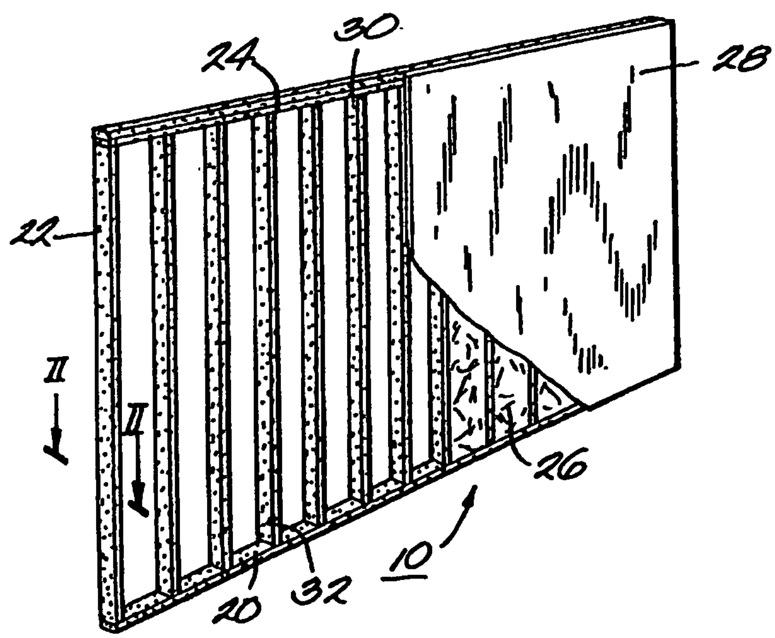
(54) Title: CEMENTITIOUS MATERIAL BASED LUMBER PRODUCT

(57) Abstract

A method for constructing buildings using cementitious–material–based non–wood construction members (32, 52) and buildings constructed from the cementitious–material–based non–wood members. A method for manufacturing high–performance fiber–reinforced cellular concrete members and the use of the cellular concrete members (32, 52) as replacements for conventional wood lumber construction members. The cellular concrete members have the necessary strength, durability, nailability, and sawability (108) for substitution of wood members in wood–frame construction applications.



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CEMENTITIOUS MATERIAL BASED LUMBER PRODUCT

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to cementitious-material-based non-wood products for use in construction and for use as substitutes for dimensional lumber or corresponding engineered wood products and in the same applications and dimensions as wood lumber products.

Background Prior Art

In the United States, wood lumber products have formed the primary structural elements or building materials for many types of construction, especially in the single- and multi-family housing sector. A large segment of the U.S. home construction industry revolves around the use of common wood lumber framing systems for walls comprising 2x4's or 2x6's placed on 16-inch centers and floors constructed of 2x10's on 16-inch centers. Skilled labor has been trained to assemble these specific types of framing. Special equipment has also been designed and manufactured to perform and speed up the process of assembly. Therefore, any proposed changes in construction techniques that seek to significantly alter established construction practices would not be viewed favorably by the construction industry nor the marketplace. For years, lumber has been abundant and relatively inexpensive. Also, its natural structural properties and its ease of manufacture have assured its dominant position. However, with the growth of the economy, dwindling forest resources, and the emerging significance of global environmental issues such as the greenhouse effect, there is a need to re-assess the widespread use of wood-based products in building construction.

Over the years, many substitute building construction products have been brought into the market with varying degrees of success. However, none of

these products are compatible with current methods and techniques for wood frame construction, the large pool of labor skilled in wood-frame construction, and the equipment developed and available to that industry. New concepts have either attempted to change the construction or structural system altogether, or required construction workers to learn new skills and use new forms of equipment to perform the construction work. These prior art concepts also affected conventional ways of handling other aspects of construction such as plumbing and electrical work. For example, replacing the wood frame wall concept with conventional concrete walls or Insulated Concrete Form (ICF) walls requires construction workers skilled in concrete forming, placement, and curing; affects the way the electrical and plumbing work is done; and results in a wall system far heavier than the corresponding wood frame system. Heavier building elements result in higher inertia forces during earthquakes. Walls built with conventional cellular concrete blocks or panels are lighter, but have very low compressive strengths. Because of their brittleness, their response to lateral loading caused by earthquakes in seismic zones or caused by hurricanes or other strong winds is an area of major concern.

Steel studs have been developed and used to approximate wood frame construction. These hollow studs are made of cold-formed steel. They are generally not nailable, although metal screws are used. They are generally not sawable in the field and need to be pre-cut to exact lengths. In contrast to the relative flexibility afforded plumbers or electricians in wood-frame buildings, the steel stud frames have pre-placed positions for the passage of plumbing or electrical hardware. Due to the high thermal conductivity of steel, ghost shadowing, which comprises the appearance of a shadow of the metal stud on the gypsum board wall, has also been a problem. Steel

studs can also be susceptible to local or general buckling when subjected to extreme loads or heat.

U.S. Patent 5,479,751 discloses a method and apparatus for fabrication of wood substitute products containing cement and synthetic resin. The disclosed product is described as having sawability and fastener-holding properties. The product includes an outermost casing (hollow tubular body) which is filled with cement and resin. Because the cement mixture inside the tube is not reinforced for tensile stresses, the casing provides that structural function. Because it is common practice to remove parts of the dimensional lumber for fitting and other purposes in wood-frame construction, any cutting of the casing in this product would compromise the structural integrity of the member.

Aerated cellular concrete is a light-weight cement-based product that has been used in some concrete houses. A few commercial manufacturers produce cellular concrete blocks and panels in the United States. However, the structural systems used in such cases are typically based on load-bearing walls, which is a significant departure from framing systems used in wood houses. Cellular concrete is both sawable and nailable. However, special nails are generally recommended to provide better nail pull-out capacities. The strength of common cellular concrete is relatively low. Because of its brittleness, fabrication of members such as 2x4's from cellular concrete is not feasible because they would easily break. In general, the ingredients of cellular concrete include Portland cement, silica sand, lime, water, and a foaming or aerating agent which is typically aluminum powder. Cellular concrete plants use autoclaves to cure the cast blocks.

The prior art also includes fiber-reinforced concrete, and significant research has been performed particularly in the last decade on various applications

of fiber-reinforced concrete including the use of fiber-reinforced cellular concrete building panels for construction of an envelope surrounding buildings for protection against hurricane-induced missiles. Fiber reinforced cellular concrete has included polypropylene fibers added to cellular concrete to produce 4-in. thick panels. Although this material exhibits improved toughness and ductility which are good properties against missile impact, its compressive strength is low (250 psi or approximately 1/20th of conventional concrete).

U.S. Patent 5,002,620 discloses a laminated or sandwiched panel system in which layers of fiber-reinforced concrete are cast against each other. The layers include a dense layer without air bubbles sandwiched with a lighter layer of cellular concrete. A vapor barrier is placed between the two mating layers. The dense layer of non-cellular material serves as the structural, load carrying element while the cellular layer provides insulation qualities. The fiber-reinforced cellular material discussed in U.S. Patent 5,002,620 does not provide the necessary structural strength to permit use of this product in the form of dimensional lumber and as a primary structural element.

It is important to realize that in wood-frame construction, the imposed loads are being carried by the relatively small cross-sectional areas of the 2x4's or 2x6's as opposed to a wall system where a relatively large area and moment of inertia supports the load. Stress levels are far higher in dimensional lumber members than in a wall system. This substantially increases the strength requirements for the dimensional lumber member. The increased strength must be accommodated in the design of the lumber member. In addition to the strength issue, the nailability, sawability, and weight issues are other important factors in a dimensional lumber member. For example,

the likely result of attempts to increase compressive strength would be a reduction in nailability and sawability, and an increase in weight. Attempts to increase tensile strength through addition of more fibers leads to dispersion problems and other issues that must be resolved.

U.S. Patent 4,351,670 and U.S. Patent 4,465,719 disclose methods of making, and structural elements incorporating, a lightweight concrete. The lightweight aggregates for this concrete consist of broken-up pieces of cellular concrete that are coated with cement slurry. This material does not include fibers, and can be cast in a casing to form a composite building element. This invention is intended to introduce a new source of lightweight aggregate for concrete.

U.S. Patent 5,685,124 discloses a folded plate panel using boards made of wood. Veneers are attached to one or both sides of the ridges of the folded plate. The hollow spaces thus created are filled with sound- and heat-insulating materials. Lightweight concrete and foamed concrete can be used as insulation filling the hollow spaces. The concrete is not intended to serve a structural function in this invention.

U.S. Patent 2,156,311 discloses a "cement-fibrous" lightweight material with fireproof and waterproof properties based on wood pulp and cement. The patent describes a manufacturing process involving filtering to remove water and roller forming of cement panels. This material is not an aerated cellular concrete.

U.S. Patent 2,153,837 discloses the addition of a small amount of wood pulp to achieve uniformity in cellular concrete walls. The wood pulp is not intended to serve a structural function, but to ensure uniformity of the final product.

SUMMARY OF THE INVENTION

The invention includes a method for constructing buildings using cementitious-material-based non-wood

construction products and buildings constructed from such cementitious-material-based non-wood construction products. The invention further includes a method for manufacturing high-performance fiber-reinforced cellular concrete (HPFRCC) products and the use of such products as replacements for conventional wood lumber construction products. The products of the invention have the necessary strength, durability, nailability, and sawability for direct substitution for dimensional wood lumber in wood-frame construction applications.

More particularly, the invention includes cement-based HPFRCC products for use in direct substitution of dimensional lumber such as 2x4's, 2x6's, 2x10's, etc. which are typically used in wood-frame construction. The construction products embodying the invention have load capacities in flexure, compression, tension, and shear that can equal or exceed the corresponding base values for stud grade lumber commonly used in construction. The geometries of the developed products can be identical to the corresponding conventional wood products. The products embodying the invention can also be made in a variety of shapes and sizes other than dimensional lumber sizes and shapes. They are nailable using common nails, with nail pull-out capacities comparable to wood, and sawable using common hand saws or electric saws. The basic material used in the products has approximately half the specific weight of conventional concrete, with substantially increased toughness (energy absorption capability) and ductility (ability to stretch without rupture, or squeeze without disintegration) when compared to conventional concrete or wood. The product embodying the invention has excellent insulation properties, is not susceptible to long-term deterioration due to termites or other harmful parasites affecting timber products, does not suffer from common lumber imperfections such as knots, is fire resistant, is shatter (impact) resistant, and can be made in a variety of colors, lengths, and

assemblies. The product also has the unique potential of maintaining and using conventional methods and equipment used for wood frame construction (walls, floors, decking, etc.) without the need to further jeopardize dwindling, environmentally-crucial global forest product or timber resources. It also offers options for pre-fabricated framing panels for assembly at the building site.

These and other features and advantages of the invention will become apparent to those skilled in the art upon review of the following detailed description of the preferred embodiment of the invention, which is given by way of example only, reference being made to the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a wall frame system embodying the invention.

Fig. 2 shows a schematic cross section of a 2x4 product illustrated in Fig. 1.

Fig. 3 shows a floor system embodying the invention.

Fig. 4 shows a roof truss assembly embodying the invention.

Fig. 5 is a schematic of a method for manufacturing high performance fiber reinforced cellular concrete embodying the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 illustrates a frame assembly 10 for use as a structural component of a building, such as a wall.

The frame assembly 10 includes a plurality of studs 22 that are spaced-apart and fastened to a sole plate 20 by nailing or by the use of threaded fasteners such as screws or bolts at the stud bottom ends 32. The sole plate 20 is horizontally oriented, and the studs 22 are vertically oriented. A top plate 24 is

fastened in the same manner to the stud top ends 30 of studs 22. The top plate 24 is horizontally oriented, and parallel to the sole plate 20. All studs 22, the sole plate 20, and the top plate 24 are made from high performance fiber-reinforced cellular concrete (HPFRCC), which will be discussed in more detail below.

Once the frame assembly 10 is completed, insulation 26 can be installed between the studs 22, and wallboard 28 can be applied to the frame assembly 10 using the same techniques as are used for wood lumber wall assemblies.

Fig. 2 illustrates a schematic cross-section of a piece of dimensional lumber formed from HPFRCC, such as a 2x4 that would be used to construct the frame assembly 10 of Fig. 1. The cross-section shows a random distribution of voids 40 formed in the concrete. The cross-section also shows the randomly oriented and randomly distributed fibers 42 in the concrete.

Fig. 3 illustrates a frame assembly for use as a structural component of a building, such as a floor.

The frame assembly includes a plurality of joists 52 that are spaced-apart and parallel and fastened to end plates 50 by nailing or by the use of threaded fasteners such as screws or bolts at both ends of joists 52. Both end plates 50 and all of the joists 52 are horizontally oriented, with the two end plates 50 parallel to each other and the joists 52 oriented perpendicularly to both end plates 50. In one embodiment of the invention, the joists 52 and end plates 50 are nailed together in the same way as wood lumber members are nailed together. All joists 52 and both end plates 50 are made from HPFRCC, which will be discussed in more detail below.

Once the frame assembly is completed, floor boards 54 can be applied to the frame assembly. The floor boards 54 can be nailed or secured by screws to the frame assembly.

Fig. 4 illustrates a frame assembly for use as a structural component of a building, such as a roof truss 60.

The frame assembly includes a lower chord 62 that forms the base for the roof truss 60. With the lower chord 62, the two upper chords 64 form a generally A-shaped assembly. Connecting members 66 are disposed between and fastened to the lower chord 62 and the upper chords 64 to provide additional structural strength. The lower chord 62, upper chords 64, and connecting members 66 are fastened by nailing or by the use of threaded fasteners such as screws or bolts. Additionally, all joints are reinforced using plate-type gussets 68. The lower chord 62, upper chords 64, and connecting members 66 are made from HPFRCC, which will be discussed in more detail below. In one embodiment of the invention, the lower chord 62, upper chords 64, and connecting members 66 are nailed together in the same way as wood lumber members are nailed together.

The uses of this invention are not limited to those described. HPFRCC dimensional lumber members and the methods disclosed herein may be used in the fabrication of pallets, fencing, decking, cribbing, railroad ties, shelving, and any other products that can be fabricated from wood lumber.

Fig. 5 illustrates a process for manufacturing lumber products from HPFRCC. The following components are mixed in a tank 80 containing a high-speed mixer 82.

- Portland Cement 84 - In general, Type I cement can be used. However, other cement types can also be used to achieve particular properties.
- Fly ash 86 - Fly ash is a waste product (or byproduct) resulting from the burning of coal in power plants. It has cementitious properties, but is lighter than cement. Class F Fly ash is used. However, other types of fly ash and other

pozzolans (such as silica fume) can also be used separately or in combination with each other.

- Water 88 - Potable water should be used. Any water that is deleterious to conventional concrete would also be unsuitable for this application.
- Fiber 90 - Many types of synthetic and natural fibers for use in concrete are commercially available (carbon, polypropylene, alkali-resistant glass, cellulose, nylon, aramid, acrylic, polyethylene, etc.) and can be used in this application individually or in combination with other fibers. The type and amount of different fibers depend on the desired strength properties ("structural" or "non-structural") and the nailability of the product. The type of fiber used not only affects the amount of fiber required, but also impacts proportioning and choice of other mix ingredients. The ability to properly disperse the fibers within the mix is another important consideration. Due to cost, stiffness, and strength considerations, polypropylene fibers are used in the developed structural products. Monofilament, multifilament, and fibrillated fibers are commercially available.
- Superplasticizer 92 - A high range water-reducing admixture or superplasticizer 92 (meeting ASTM C494 F&G requirements) is used to improve workability of the mix.
- Aerating or foaming compound 94 - Aluminum powder is used to aerate the mixture. The fineness of powder should be appropriate for production of cellular concrete. Foams or other compounds capable of introducing gas bubbles in concrete can be used in lieu of aluminum powder.
- Color pigments 96 if a colored product is desired - A large selection of color pigments is commercially available from suppliers such as Davis Colors of Los Angeles, CA. These pigments

can be used to introduce the desired colors throughout the product. Alternatively, surface color can be applied at the end of production by immersion in a paint bath or by brushing. Although the permeability of the developed products is very low, sealers can also be applied to the surface in this manner if desired, especially in outdoor applications.

The mix design must consider the impact of different materials on the resulting properties of the product.

In other embodiments, sand or a variety of lightweight sands can also be used. However, the inclusion of sand will alter the resulting properties of HPFRCC lumber members including their compressive strength. If used, silica sand can reduce the working life of many conventional saw cutting blades.

The mixing process involves mixing fly ash 86 and part of the water 88, and sand if used, followed by the introduction of cement 84 and color pigments 96 if used. Additional water 88 and superplasticizer 92 are added to achieve the desired workability. Then, fibers 90 are introduced and mixed thoroughly with a high-speed mixer 82 while the remainder of the water 88 and superplasticizer 92 is introduced. Finally, aluminum powder 94 is added and mixed thoroughly with the high-speed mixer 82.

The HPFRCC mixture 98 is placed in forms 100 to a height below the final desired level. The action of the aluminum powder 94 raises the level of HPFRCC mixture 98 above the final desired level. The excess HPFRCC mixture 98 is then removed 102, and the products are prepared for curing 104. Autoclaving is not required, but accelerated curing procedures may be used. In general, moist curing or steam curing followed by air curing will be used. The method of curing 104 will be based on a number of currently-available methods for curing concrete, and will be dependent on the time requirements to achieve the

necessary concrete properties, mainly compressive strength. After an initial period of curing 104, the products will be demolded 106, cut to desired dimensions 108, and further cured 110. The products can then be shipped 112 as desired.

Other production alternatives exist. For example, a large block of HPFRCC can be cast. Then, after the initial set is achieved, the block can be cut into the desired sizes using tensioned wires or high-temperature wires before proceeding with the curing processes. This process is generally used in the production of cellular concrete blocks. In another method, an extrusion process may be used for direct production of the desired sizes in lieu of the method of casting in forms. In this case, a foaming or aerating agent is introduced into the mix, and the low-slump mix is fed into the extrusion process.

Currently, there are many fabrication plants that, based on individual building drawings, pre-fabricate wood-framed building panels including walls and floors that are then transported and erected at the site. Similar work can be performed with this set of products. In fact, fabrication and assembly can be either as individual members assembled together as done in the case of wood, or HPFRCC placement and fabrication for the entire framing panel can be made in one operation. Forming and wire cutting processes may be used. Also, additional internal and external reinforcement can be placed in the connection zones to further improve performance especially in areas with risk of significant earthquakes.

The design load capacities for various grades and types of lumber products are provided in the "National Design Specification for Wood Construction and Supplement" published by the American Forest and Paper Association in Washington, D.C. These safe load capacities include inherent safety factors based on the likelihood of flaws or defects or construction

deficiencies. The ACI 318 Code for reinforced concrete requires a load factor of 1.4 for dead load and 1.7 for live load with a reduction factor of 0.9 for flexure, 0.85 for shear, and 0.7 for compression. As an example, this results in an effective safety factor of 1.54 for dead load and 1.87 for live load (both for flexure). The "Recommended Practice for Autoclaved Aerated Concrete" published by RILEM recommends a safety factor of 1.8 for flexure and 2.1 for compression in cellular concrete. RILEM, the International Union of Testing and Research Laboratories for Materials and Structures, is located in France. Considering that the new class of products (HPFRCC) discussed here is technically a type of cellular concrete, it is reasonable and conservative to adhere to the currently-existing safety factors for cellular concrete (i.e., 1.8 for flexure and 2.1 for compression). The safety factors apply to the ultimate strength of the product in compression, tension, flexure, and shear. It is also appropriate to include a second serviceability limit state criterion against flexural cracking (i.e. allowable stresses must be less than the stress at first crack). For this set of products, a factor of safety of 1.25 against flexural cracking is proposed (similar to that existing for prestressed concrete in ACI 318) in addition to factors of safety of 1.8 and 2.1 against failure.

The type and quantities of different materials, production processes, and curing methods affect the properties of the resulting product. The following ranges for the quantities of various products (as a percentage of total weight) can be used to achieve a wide range of properties for both structural and non-structural product grades:

- Portland Cement: 18%-40%
- Fly ash: 0%-50%
- Silica Fume: 0%-25%
- Sand: 0%-40%

- Water: 20%-30%
- Polypropylene Fiber: 0.4%-3.2%
- Superplasticizer: 0%-0.6%
- Aluminum Powder: 0.012%-0.048%
- Color Pigment: 0%-3.5%

EXAMPLE

The following mix proportions with a combination of moist or steam and air curing will result in minimum service load design (safe) stresses of 700 psi flexure, 900 psi compression, and 100 psi shear (all based on 28-day strengths). These safe load capacities exceed comparable base values for typical STUD grade lumber specified in the National Design Specification for Wood Construction.

	weight %
• Portland Cement (Type I):	36.3
• Fly ash (Class F):	36.3
• Water:	23.95
• Polypropylene Fiber (FIBERMESH fiber from Fibermesh, Chattanooga, TN, 1/2 in. long, multifilament):	1.6
• Aluminum Powder:	0.02
• Superplasticizer (WRDA 19):	0.44
• Color Pigment, if used:	1.5

The above mixture will result in a minimum 28-day compressive strength of 2000 psi, minimum flexural strength of 1300 psi (based on moment strength and uncracked section properties), a minimum first crack of 900 psi, a density of 75 lb. per cubic foot, and conventional nail pull-out capacities comparable to STUD grade lumber (per the Uniform Building Code tables). Thus, the above mixture will meet or exceed the cellular concrete safety factors described above. It should be noted that the compressive strength of the HPFRCC is expected to increase substantially as the

HPFRCC ages beyond 28 days. This is due to the presence of a large amount of fly ash in the mix.

For the non-structural product grade, the quantities of cement and fibers can be reduced, while sand or lightweight sand can be used to replace part or all of the fly ash. To reduce the weight of the product, the amount of aluminum powder can be increased. This will, however, reduce the compressive strength of the product.

In general, the advantages of the products embodying the invention can be summarized as follows. These products can be made in a variety of sizes and shapes including all dimensional lumber shapes. These products can be made in different colors and lengths. Wood lumber prices per board foot increase substantially with increased length and size. However, these products can be made in very long lengths or large cross sections without a major cost premium. These products can be made with sufficient strength parameters to serve as structural members and directly replace dimensional lumber in wall, floor, decking, and other applications. These products are nailable using common nails with nail pull-out capacities comparable to conventional lumber. These products are sawable using hand saws and a variety of electric saws commonly used for conventional lumber. They can also be drilled. These products have excellent insulation properties and have very low water permeabilities. The toughness and ductility of these products are better than conventional concrete or wood. These products do not suffer from common wood defects such as knots. Through proper production and quality control procedures, they can be made free of concrete defects such as honeycombs. These products are lightweight concrete with a maximum specific weight of approximately half the specific weight of conventional concrete. These products are not susceptible to attack by harmful insects or parasites such as termites.

These products are fire resistant and shatter (impact) resistant. These products could make available highly-efficient wood-frame-type housing in areas of the world not possessing forest resources, such as desert areas. These lighter and more ductile structures offer a number of advantages including better resistance to seismic events. These products can positively impact the environment by substantially reducing dependence on the world's environmentally-crucial forest resources while using a large quantity of waste products such as fly ash. These products offer new possibilities regarding pre-fabricated panels for assembly at the building site. These products allow new architectural design possibilities through the use of colors and the ability to create members with different surface finishes by using textured forms, for example.

While a preferred embodiment of the invention has been disclosed by way of example, various obvious modifications will become apparent to those skilled in the art. Thus, the scope of the invention should be limited to only by the spirit and scope of the following claims.

I Claim:

1. A frame assembly for use in construction of a building, the frame assembly comprising

a pair of elongated linear structural members positioned in spaced apart relationship;

at least one elongated linear structural member extending between the spaced apart pair of elongated linear structural members, at least one of the elongated linear structural members being formed from fiber reinforced cellular concrete.

2. A frame assembly as set forth in claim 1, wherein each of said elongated linear structural members is formed from fiber reinforced cellular concrete.

3. A frame assembly as set forth in claim 1, wherein at least one of the elongated linear structural members is joined to another of the elongated linear structural members by a fastener extending through at least a portion of the one of the elongated linear structural members into another of the elongated linear structural members.

4. A frame assembly as set forth in claim 3, wherein the fastener is a nail.

5. A frame assembly as set forth in claim 3, wherein the fastener is a threaded fastener.

6. A frame assembly as set forth in claim 1, wherein said at least one of the elongated linear structural members is made from cementitious material mixed with water, fiber and an aerating material.

7. A frame assembly as set forth in claim 6, wherein the aerating material is selected from the group consisting of: aluminum powder and a foaming agent.

8. A method for manufacturing a frame assembly for use in building construction, the method including the steps of:

forming a plurality of elongated linear structural members from fiber reinforced cellular concrete, and

joining the elongated linear structural members together with fasteners that extend through the elongated linear structural members and so as to form a frame.

9. A method for manufacturing a frame assembly as set forth in claim 8, wherein the step of joining the elongated linear structural members together includes the step of driving a nail through one of the elongated linear structural members into another of the elongated linear structural members to join the one of the elongated linear structural member to said another elongated linear structural member.

10. A method for manufacturing a frame assembly as set forth in claim 8, wherein the step of forming includes making a cementitious material mixed with water, fiber and an aerating material.

11. A method for constructing a building using non-wood construction products comprising the steps of:

a) constructing a plurality of planar frame sections from elongated elements, at least a plurality of said elongated elements being formed from fiber-reinforced cellular concrete, said step of constructing including fastening a plurality of elongated intermediate elements having first and second ends to an elongated first end element at the first ends of the intermediate elements such that each intermediate element is substantially parallel to the other intermediate elements and the intermediate elements are substantially perpendicular to the first end element, and fastening an elongated second end element to the plurality of intermediate elements at the second ends of the intermediate elements such that the second end element is substantially perpendicular to the intermediate elements and substantially parallel to the first end element; and

b) fastening a first planar frame section to a second planar frame section such that the plane of the first frame section is substantially perpendicular to the plane of the second frame section.

12. A method for constructing a building as set forth in claim 11, wherein the step of forming includes making a cementitious material mixed with water, fiber and an aerating material.

13. A method for constructing a building as set forth in claim 12, wherein the aerating material is selected from the group consisting of: aluminum powder and a foaming agent.

14. The method for constructing a building as set forth in claim 12, wherein the cementitious material is selected from the group consisting of: fly ash, cement and silica fume.

15. The method for constructing a building as set forth in claim 12, wherein the fiber is selected from the group consisting of: carbon, polypropylene, alkali-resistant glass, cellulose, nylon, aramid, acrylic, and polyethylene.

16. The method for constructing a building as set forth in claim 11, wherein the step of fastening includes the step of driving a nail through one of the elongated members into another of the elongated members to join the one of the elongated member to said another elongated member.

17. The method for constructing a building as set forth in claim 11, wherein the step of fastening includes the step of driving a threaded fastener through one of the elongated elements into another of the elongated elements to join the one of the elongated elements to said another elongated element.

18. A method for constructing a building frame section using non-wood construction products comprising the steps of:

a) fastening a plurality of elongated intermediate elements having first and second ends to an elongated first end element at the first ends of the intermediate elements such that each intermediate element is substantially parallel to the other intermediate elements and the intermediate elements are substantially perpendicular to the first end element; and

b) fastening an elongated second end element to the plurality of intermediate elements at the second ends of the intermediate elements such that the second end element is substantially perpendicular to the intermediate elements and substantially parallel to the first end element, at least one of said intermediate or first or second end elements being formed from fiber-reinforced cellular concrete.

19. A method for constructing a building frame section as set forth in claim 18, wherein the step of forming includes making a cementitious material mixed with water, fiber and an aerating material.

20. A method for constructing a building frame section as set forth in claim 19, wherein the aerating material is selected from the group consisting of: aluminum powder and a foaming agent.

21. The method for constructing a building frame section as set forth in claim 19, wherein the cementitious material is selected from the group consisting of: fly ash, cement and silica fume.

22. The method for constructing a building frame section as set forth in claim 19, wherein the fiber is selected from the group consisting of: carbon, polypropylene, alkali-resistant glass, cellulose, nylon, aramid, acrylic, and polyethylene.

23. The method for constructing a building frame section as set forth in claim 18, wherein the step of fastening includes the step of driving a nail through one of the elongated elements into another of the elongated elements to join the one of the elongated elements to said another elongated element.

24. The method for constructing a building frame section as set forth in claim 18, wherein the step of fastening includes the step of driving a threaded fastener through one of the elongated elements into another of the elongated elements to join the one of the elongated elements to said another elongated element.

25. A structural frame for use in forming a building, the frame comprising:

a plurality of elongated intermediate elements having first and second ends;

an elongated first end element fastened to the first ends of the intermediate elements such that each intermediate element is substantially parallel to the other intermediate elements and the intermediate elements are substantially perpendicular to the first end element; and

an elongated second end element fastened to the plurality of intermediate elements at the second ends of the intermediate elements such that the second end element is substantially perpendicular to the intermediate elements and substantially parallel to the first end element, at least one of said intermediate or first or second end elements being formed from fiber-reinforced cellular concrete.

26. A structural frame as set forth in claim 25, wherein said at least one of the elongated elements is made from cementitious material mixed with water, fiber and an aerating material.

27. A structural frame as set forth in claim 26, wherein the aerating material is selected from the group consisting of: aluminum powder and a foaming agent.

28. A structural frame as set forth in claim 26, wherein the cementitious material is selected from the group consisting of: fly ash, cement and silica fume.

29. A structural frame as set forth in claim 26, wherein the fiber is selected from the group consisting of: carbon, polypropylene, alkali-resistant glass, cellulose, nylon, aramid, acrylic, and polyethylene.

30. A structural frame as set forth in claim 25, wherein the elongated elements are fastened with a fastener extending through at least a portion of the one of the elongated elements into another of the elongated elements.

31. A structural frame as set forth in claim 30, wherein the fastener is a nail.

32. A structural frame as set forth in claim 30, wherein the fastener is a threaded fastener.

33. A method for making non-wood elongated rigid elements for use in building construction, the method comprising the steps of:

a) mixing a cementitious material and water to produce a concrete mixture;

b) blending a fiber into the concrete mixture;

c) blending an aerating material into the concrete mixture;

d) placing the concrete mixture into a form;

e) curing the concrete mixture;

f) removing the concrete mixture from the form; and

g) finishing the concrete mixture to form at least one elongated rigid structural element.

34. A method for making non-wood elongated rigid elements as set forth in claim 33, wherein the aerating material is selected from the group consisting of: aluminum powder and a foaming agent.

35. The method for making non-wood elongated rigid elements as set forth in claim 33, wherein the cementitious material is selected from the group consisting of: fly ash, cement and silica fume.

36. The method for making non-wood elongated rigid structural elements as set forth in claim 33, wherein the fiber is selected from the group consisting of: carbon, polypropylene, alkali-resistant glass, cellulose, nylon, aramid, acrylic, and polyethylene.

37. The method for making non-wood elongated rigid elements as set forth in claim 33, further comprising the step of blending a superplasticizer into the concrete mixture.

38. The method for making non-wood elongated rigid elements as set forth in claim 33, further comprising the step of blending sand into the concrete mixture.

39. The method for making non-wood elongated rigid elements as set forth in claim 33, further comprising the step of waiting for the action of the aerating material to raise a level of concrete mixture above a final desired level.

40. The method for making non-wood elongated rigid elements as set forth in claim 39, further comprising the step of removing concrete mixture that has risen above the final desired level, leaving a remaining concrete mixture.

41. The method for making non-wood elongated rigid elements as set forth in claim 33, wherein the step of finishing includes cutting the concrete mixture.

42. A method for making non-wood elongated rigid structural elements for use in building construction, the method comprising the steps of:

a) mixing a cementitious material and water to produce a concrete mixture;

b) blending a fiber into the concrete mixture;

c) blending an aerating material into the concrete mixture;

d) extruding the concrete mixture;

e) curing the concrete mixture; and

f) finishing the concrete mixture to form at least one elongated rigid structural element.

43. The method for making non-wood elongated rigid structural elements as set forth in claim 42, wherein the aerating material is selected from the group consisting of: aluminum powder and a foaming agent.

44. The method for making non-wood elongated rigid structural elements as set forth in claim 42, wherein the cementitious material is selected from the group consisting of: fly ash, cement and silica fume.

45. The method for making non-wood elongated rigid structural elements as set forth in claim 42, wherein the fiber is selected from the group consisting of: carbon, polypropylene, alkali-resistant glass, cellulose, nylon, aramid, acrylic, and polyethylene.

46. The method for making non-wood elongated rigid structural elements as set forth in claim 42, further comprising the step of blending a superplasticizer into the concrete mixture.

47. The method for making non-wood elongated rigid structural elements as set forth in claim 42, further comprising the step of blending sand into the concrete mixture.

48. The method for making non-wood elongated rigid structural elements as set forth in claim 42, wherein the step of finishing includes cutting the concrete mixture.

49. A method for making non-wood elongated rigid structural elements for use in building construction, the method comprising the steps of:

a) mixing a cementitious material and water to produce a concrete mixture;

b) blending a fiber into the concrete mixture;

c) blending an aerating material into the concrete mixture;

d) making a block of the concrete mixture;

e) finishing the block to form at least two elongated rigid structural elements; and

f) curing the elongated rigid structural elements.

50. The method for making non-wood elongated rigid structural elements as set forth in claim 49, wherein the aerating material is selected from the group consisting of: aluminum powder and a foaming agent.

51. The method for making non-wood elongated rigid structural elements as set forth in claim 49, wherein the cementitious material is selected from the group consisting of: fly ash, cement and silica fume.

52. The method for making non-wood elongated rigid structural elements as set forth in claim 49, wherein the fiber is selected from the group consisting of: carbon, polypropylene, alkali-resistant glass, cellulose, nylon, aramid, acrylic, and polyethylene.

53. The method for making non-wood elongated rigid structural elements as set forth in claim 49, further comprising the step of blending a superplasticizer into the concrete mixture.

54. The method for making non-wood elongated rigid structural elements as set forth in claim 49, further comprising the step of blending sand into the concrete mixture.

55. The method for making non-wood elongated rigid structural elements as set forth in claim 49, wherein the step of finishing includes cutting the block.

56. The method for making non-wood elongated rigid structural elements as set forth in claim 55, wherein the step of cutting includes cutting the block using tensioned wires.

57. The method for making non-wood elongated rigid structural elements as set forth in claim 55, wherein the step of cutting includes cutting the block using high-temperature wires.

58. A lumber product for use in building construction, the lumber product comprising fiber-reinforced cellular concrete made from a cementitious material, water, fiber, and an aerating material, made to form an elongated rigid element of lumber-industry-standard dimensions.

59. The lumber product of claim 58, wherein the cementitious material is selected from the group consisting of: fly ash, cement and silica fume.

60. The lumber product of claim 58, wherein the aerating material is selected from the group consisting of: aluminum powder and a foaming agent.

61. The lumber product of claim 58, wherein the fiber is selected from the group consisting of: carbon, polypropylene, alkali-resistant glass, cellulose, nylon, aramid, acrylic, and polyethylene.

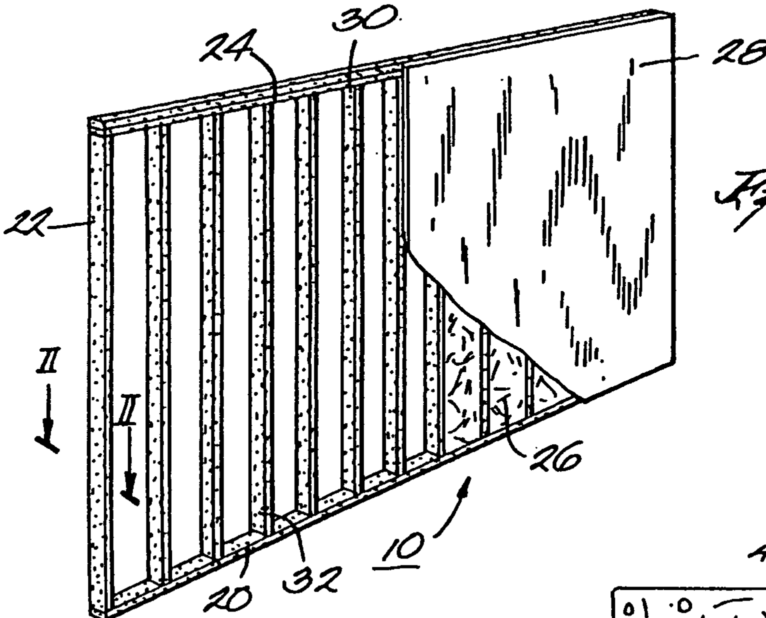

Fig. 1

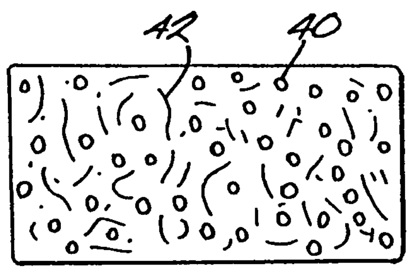

Fig. 2.

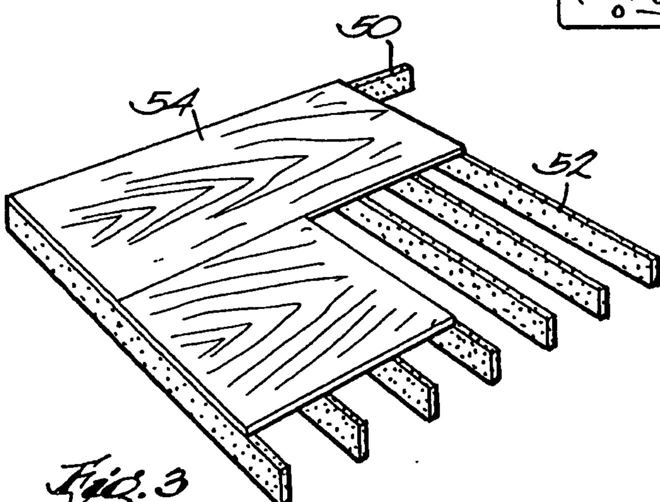

Fig. 3

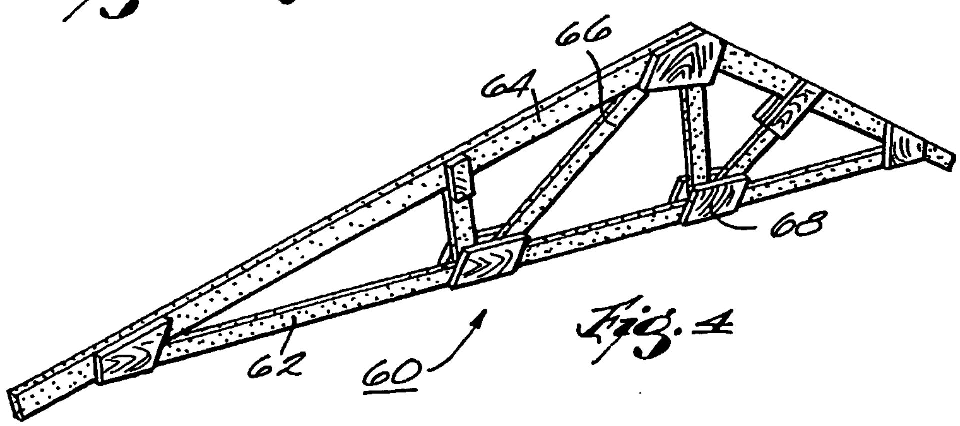

Fig. 4

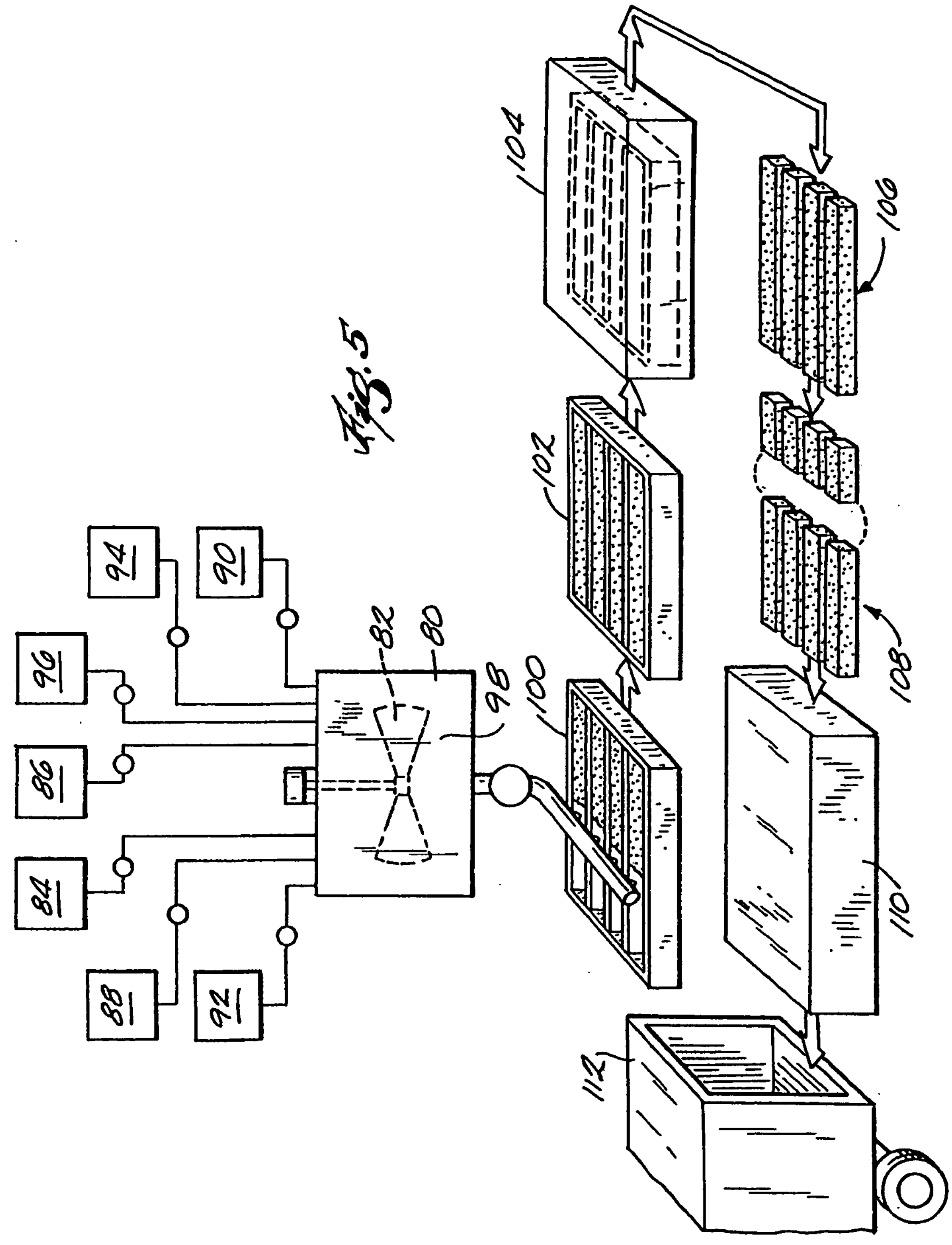

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/10530

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :E04G 21/14; E04C 2/38; B29C 70/00
US CL :52/745.1, 639, 656.1; 29/897.312, 897.32, 897.35; 264/148, 297.9
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,563,851 A (LONG) 14 January 1986, Fig. 1 and col. 2, lines 35-37.	1-32
X --- Y	US 5,108,679 A (RIRSCH et al.) 28 April 1992, cols. 4-8.	33-61 --- 1-32
Y	US 5,391,245 A (TURNER) 21 February 1995, Figs. 1-3 and col. 4, lines 25-30.	1-32
X --- Y	US 5,707,474 A (ANDERSEN et al.) 13 January 1998, Figs. 4-9 and cols. 15-70.	33-61 --- 1-32

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
06 SEPTEMBER 1999	07 OCT 1999

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/10530

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,897,703 A (HATAKEYAMA et al.) 27 April 1999, cols. 2-7.	1-61

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/10530

B. FIELDS SEARCHED
Minimum documentation searched
Classification System: U.S.

52/745.1, 639, 656.1, 642, 745.09, 745.13; 29/897.31, 897.312, 897.32, 897.35; 264/42, 45.3, 138, 145, 148, 157, 239, 297.1, 297.8, 297.9